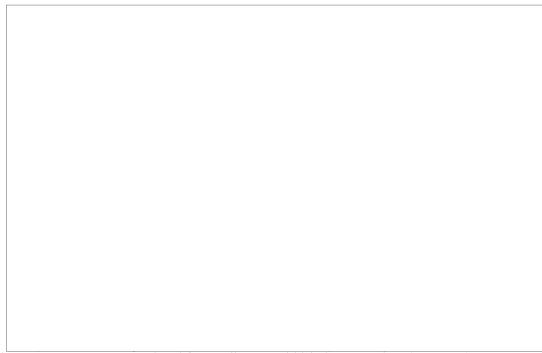


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Determining the Area of Possible Simultaneous Thaw in Watersheds  
of Central Asian Rivers

Meteorologiya i Gidrologiya, V. L. Shul'ts  
Moscow, April 1948



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DETERMINING AREA OF POSSIBLE SIMULTANEOUS THAW  
IN WATERSHEDS OF CENTRAL ASIAN RIVERS

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The basic feeder source of Central Asian rivers is represented by their waters. Therefore the key to understanding the formation mechanism of drainage of Central Asian rivers can be furnished by the sequence in thawing time of water in its solid phase. In other words, in order to solve the problem of intra-annual drainage distribution of rivers, it is necessary first of all to know at any time the area of simultaneous thaw (In the future by the word "thaw" we shall denote processes of snow and ice melting).

In Central Asian surroundings, where the small river watersheds (in the order of 100 square kilometers) are distinguished by a considerable amplitude of elevations (usually in excess of 2000 meters), no simultaneous thaw over the entire watershed area can take place. At any given time thaw takes place over a certain portion of the watershed, and therefore only a portion and not the entire watershed is instrumental in creating a flooded condition. It is obvious that the area of simultaneous thaw will embrace at any time a portion of the watershed, bounded by the "thaw front," i.e., by a line connecting points where the thaw begins, and by the "thaw rear," which is a line connecting points where the snow begins to descend. Since not all of the area bounded by the "thaw front" and "thaw rear" is covered with snow, it is better to refer to this area as the "area of possible simultaneous thaw," keeping in mind that a portion of it would be free of snow at the time of thaw. This phenomenon is explained by the extreme variety of formation and shading of snow

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deposits in mountains. The area of possible simultaneous thaw will change in size from time to time and will shift its location, ascending gradually along the area of the watershed. By observing the movements of the "thaw rear" and "thaw front" over a period of one year in a given watershed, and thereby knowing the area of possible simultaneous thaw at any time, as well as having the data pertaining to the average intensity of thaw at that time, it is possible to get an idea of the amount of thaw water supply into the hydrographic network of the watershed, neglecting, as yet, losses due to losses of snow and losses over the flow path. It is understandable that knowledge of the area of possible simultaneous thaw and its intensity will considerably facilitate the estimate of the trans-boundary drainage distribution of thaw waters to non-explored directions, as well as of non-explored rivers.

What can be considered by the "front" and "rear" of thawing? Without dwelling in detail upon this question, let us point out that the "thaw front" can be taken as location of the zero isotherm 11 m ~~approximately~~<sup>at</sup> 13 hours. Actually, it was shown by P. P. Fes'tvin that thaw always takes place only with the average daily air temperatures of 2 degrees and higher. Not denying the possibility of thawing when the daily 12-hour air-temperature is below zero degrees (due to solar radiation), we are still prone to state that, first, such thawing cannot be intensive and, second, that it will hardly result in any drainage into the hydrographic network. It is more logical to assume that in the course of days with negative 12-hour air-temperatures, the heat due to solar radiation would be expended in recrystallization of snow. This assumption is most reasonable, if we recall that the non-recrystallized snow can retain up

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to 40 - 45 percent of water, and that firm snow, while only seldom, can retain up to 20 percent of water (1). Just on account of this, and since, until the formation of passageways in snow, thaw waters move with reduced velocities, drainage from the areas of the Moscow aeroneurological station took place only at positive average daily temperatures. With the average daily air temperature about 5 degrees, drainage began on the first day; with temperatures of about 1.5 degrees, on the second or third day; and with a temperature of 0.8 degree, it began on the sixth day. The total of the average daily temperatures prior to the commencement of drainage varied between 2 and 2.3 degrees (2). Note: "13-hour" is to be taken as "1300", or "1:00 PM".

The assumption that until the 13-hour air-temperature does not exceed zero degrees no intensive thawing takes place, and no consequent flow of thaw waters into the hydrographical network, is in good agreement with the data obtained at high altitude stations, which, as a rule, show the absence of perceptible decrease in thickness of the snow layer until the onset of positive 13-hour air-temperatures. This assumption is also corroborated by the lack of increased water consumption in rivers until such time that the zero 1-hour isotherm does embrace appreciable areas of watersheds.

Thus, the location of the "thaw front" can be approximately determined by the location of the 13-hour zero isotherm.

At first consideration the problem of "thaw rear" appears to be more definite than that of the "thaw front." However, it is not so. Actually, during the time of intensive thaw it is possible to observe the boundary above which lies the snow layer, not always solid, but still occupying a considerable portion of the area. Below this

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boundary, snow remains only in deep and comparatively narrow ravines and folds, where a several-meter layer of it has formed during the cold period of the year. Very frequently the bottom ends of such snowdrifts, which form fancy patterns over mountain slopes, descend 1000 meters and more below the boundary of relatively solid snow layer; and toward the end of the thaw period, if the reservoir is not situated above the constant snow line, those snowdrifts represent the basic source of "thaw water supply" for rivers. Therefore, we can distinguish two lines of "thaw rear": (1) the line connecting the points of more or less solid snow layer — "snow layer boundary;" and (2) the line connecting the lower ends of snowdrifts — "snowdrift boundary." Below the second line there is a total lack of snow in the watershed; between the two lines snow, as a rule, occupies an insignificant area; and, finally, above the first line snow occupies most of the area — and with favorable conditions almost the entire watershed area above the snow layer boundary.

We shall now refer to the problem of determining <sup>the</sup> location of the thaw front and rear at any given time.

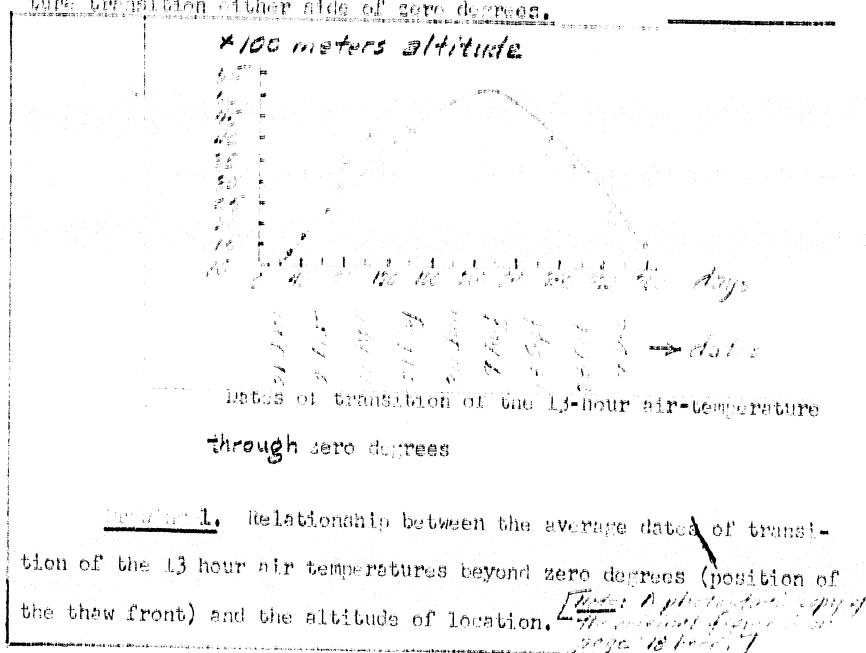
In Central Asian surroundings location of the thaw front, determined by the location of the 13-hour zero isotherm, cannot, in the first place, but depend on the altitude of location. By obtaining a relationship between the position of the zero isotherm and altitude of location it is possible to solve this problem.

With this in mind, and on the basis of data obtained at high-altitude mountain stations, there were determined spring and summer dates of when the 13-hour temperature was consistently positive, and also the autumn and winter dates when the temperature was consistently

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negative. The date of arrival of the steady 13-hour positive temperatures was considered to be the day following which negative temperatures could reoccur but over only a short period of time — less than 5 days; the intensity and stability of this negative wave being less than those of the preceding wave of positive temperatures. On the other hand, if the first positive temperature wave is supplanted by a more intense and sustained cold wave, the first wave is not taken into account. Similar criteria were used to determine the negative transition date of the 13-hour temperatures. It should be noted that in some years it is difficult to establish the date of temperature transition either side of zero degrees.



Graph 1. Relationship between the average dates of transition of the 13 hour air temperatures beyond zero degrees (position of the thaw front) and the altitude of location. *[This is a photograph copy of the original figure.]*

*[Page 18 front]*

Actually, in some years heat waves are supplanted by almost equivalent cold waves, in view of which the establishment of transition dates during these years is of somewhat arbitrary nature. Especially difficult is the establishment of the zero degrees transition dates at low altitudes (below 1,800 meters); at these altitudes during

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some years there takes place a constant change of heat and cold waves, the duration of which at times is considerable. Therefore, at low altitudes transition dates during some years are to a certain extent conditional.

The thus determined dates of transition of the 13-hour temperatures beyond zero degrees indicate that during respective years the position of the zero Isotherm varies within wide limits. For example at the glacier Fedchenko meteorological station, the zero Isotherm occurs during some years on 1 May, while during other years it occurs on 27 June — almost 2 months late. Such changes in the date of the zero Isotherm represent one of the main reasons for the earlier or later dates of commencement of Central Asian rivers during some years.

On the basis of the average and extreme transition dates of the 13-hour temperatures beyond zero degrees, there were established relationships between altitude location and the date of air-temperature transition beyond zero degrees. There we limit ourselves to showing such relationship only for springtime transition dates of temperature beyond zero degrees (Drawing 1).

The relationship shown in Drawing 1 indicates a rather wide dispersion of points. The most noticeable deviations from the curve are exhibited by the meteorological stations Chatkal, Angren, and Marym, especially the first one. At the cited stations springtime zero degree transition takes place from 20 to 30 days (in round numbers) later as compared with the date given by the graph. On the contrary, at meteorological stations Murgab (Pamir) and Kara-Kuli the zero degree transition is observed 20 days before the date shown

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by the curve.

Deviations from the curve cannot be attributed to latitude effect, exclusively at least, since the meteorological stations Pskom, Ters, and Karp-Kul'-Zhur, located in the northern part of this territory, are either on the curve or below the curve. On the contrary, southern meteorological stations Sary-Tash and Gisler Verchenko are above the curve; and the most southern meteorological station Khey-rovod is almost on the curve. From this it is possible to conclude that the deviation of data is basically determined by local conditions, which is actually the case. The altitude at which the transi-tion of the 13-hour temperature beyond zero degree is not generally observed, was determined by action of temperature gradients and was, in the case of this territory, taken as equal to 5,200 meters.

The relationships shown by Drawing 1 permit us to observe the velocity of displacement of the zero isotherm.

In January there is observed a slow upward displacement of the zero isotherm on the average of 0.7 meters daily. In February and March this displacement is maximum (27.9 - 27.4 meters daily); in April the displacement of the zero isotherm is slowed down in an increasingly intensive manner. In August there starts a downward displacement of the zero isotherm, at first slowly, and later considerably faster. It is interesting to note that the velocity of the autumn and winter downward displacement of the zero isotherm exceeds considerably the springtime upward displacement of the isotherm. As is seen from Drawing 1, the average (rounded figures) altitudes attained by the isotherm are:

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1 March	2,200
1 April	3,000
1 May	3,600
1 June	4,500
1 July	5,000
1 August	5,200

During certain years the position of the zero isotherm varies between the limits of:

Meters

1 March	1,500 + 2,700
1 April	2,600 + 3,500
1 May	3,300 + 4,200
1 June	4,100 + 5,500
1 July	4,750 + 5,250
1 August	5,000 + 5,300

Thus, during spring of certain years the zero isotherm can, at the same time, be located at altitudes differing from each other by more than 1,000 meters. This factor is decisive in the formation of early or late floods. Attention is directed to the small variation in position of the zero isotherm at great altitudes; this variation, coupled with the characteristics of thermal behavior — that of solar radiation during the second half of the summer, as well as with other factors, determines the considerably greater stability of fluid drainage during the second half of summer and beginning of autumn. Position of the thaw rear cannot be considered as a function of the altitude location.

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It is clearly evident that, apart from the conditions of thermal balance, it must also depend on the thickness of the snow layer. Therefore, position of the thaw rear should be considered as a function of altitude location and intensity of the snow layer. To determine this function, there were established dates of stable disappearance and appearance of snow layer according to the data of high-altitude meteorological stations.

In the stable disappearance of snow layer is understood the time date after which the snow, even if it had reappeared, did not melt again. In some cases, however, this reappearing of snow takes place after a period of time exceeding the actual duration of the regenerated snow layer. It should be noted that at high altitudes, in excess of 4,000 meters, snow may appear during all of the summer months. In a similar way we arrived at the date of stable appearance of the snow layer. In establishing the dates of appearance and disappearance of the snow layer we unfortunately did not utilize the data of all high-altitude mountain stations. At meteorological stations where the snow layer is thin it is highly unstable, appearing and disappearing several times in the course of winter, maintaining itself over comparatively long periods during some years. Such meteorological stations are, for example, Tyan Shan\*, Iskander-kul', Kara-kul', Fergab (Kemir) and others. [Note: T'ien-shan]

Like the zero degree transition of the 13-hour temperature, the dates of disappearance and appearance of snow layer may vary widely from year to year. For example, at the meteorological station on Glacier Fedchenko the date of disappearance of snow layer may fall on 24 June and 8 August; at the meteorological station Angren this date occurs on 4 April and 1 May, etc.

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In this connection there occur changes in the duration of snow layer. For example, at the meteorological station on Glacier Fedorovka the snow layer stays on between 293 and 316 days, with an average duration of 260 days; at Angren this varies from 189 to 178 days, with an average duration of 186 days, etc. This factor, together with variations in position of the zero isotherm, determines to a large degree the disappearance of the inter-annual drainage fluctuation of Central Asian rivers during the respective years.

It is of interest to note that the date of stable appearance of snow layer almost coincides with the transition dates of the 13-hour temperature below-zero degrees. Only seldom does the interval between these dates exceed 10 days. This simplifies our problem, since the position of the zero line can be taken as the position of the zero isotherm. In other words, positions of the snow front and snow rear during autumn and winter can be considered as coinciding.

It follows from the notes that we reckon the beginning of intensive thaw as the date of stable zero-degree transition of the 13-hour air temperature. It should be emphasized once more that such an assumption for locations where the snow layer is slight and disappears quickly does not at first consideration appear to correspond with actuality.

Actually, for example, at the meteorological station Iskander-Kul' over a period of years snow layer disappears prior to the zero degree transition of the 13-hour temperature. However, this factor has no material significance, since a meager snow layer can be thawed by solar radiation even at below-zero air temperatures without furnishing any river drainage.

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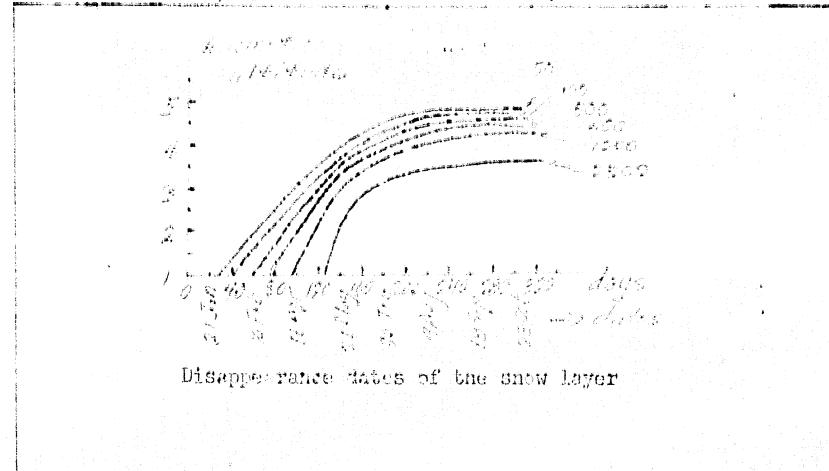
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Get a situation is observed, for example, at the watersheds of Solka, Tula and other rivers where the snow layer is meager and spots below the altitude of 2,500 - 3,000 meters, and does not furnish any river discharge; this is indicated obviously by the lowered flow, and April levels of these rivers, despite the fact that at those times the zero temperature position is above the 3,000-meter level.

From data we can draw a highly significant conclusion that during spring in a reservoir with meager snow layer over the lower and intermediate zones, the flow may lie above the threshold.

We now consider the relationship between the date of disappearance of snow layer and the Intensity and altitude factors.

Before everything else we note the scarcity of data pertaining to disappearance of snow layer in the mountainous regions of Central Asia in order to establish a reliable relationship, especially if we consider that any high-altitude meteorological stations are located at points of scarce and unstable snow layer, the thawing of which is subjected to a variety of conditions (precipitation, special weather conditions, etc.).

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**CONFIDENTIAL**

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Drawing 2. Relationship between the average date of disappearance of snow layer (position of the thaw rear) and its intensity (in water layer) at altitude location.

This circumstance has led us to look for this relationship, not on the basis of data concerning the disappearance of the snow layer, but on the basis of connection between:

- (a) the altitude of thawed snow and the sum of positive air temperatures;
- (b) the sum of positive temperatures at the time and altitude location as determined for Central Asian territory.

On the basis of the above materials obtained there was determined the relationship between the time of disappearance of snow layer, as determined by the thickness of the remaining snow, and altitude location.

An idea of how much the actual dates of disappearance of snow layer differ from those established by the relationship of Drawing 2 is furnished by Table I.

As to be expected, the greatest deviations are observed for the meteorological stations Maryn, Chitkai, and Pskem. Deviations of the first two stations is explained by the lower air temperatures at the locations of the two stations, as could be observed from Drawing 1. As regards the meteorological station Pskem, during the thaw period there a great deal of predominantly solid-state precipitation is deposited; this slows the disappearance of snow layer. Actually, if at meteorological stations Glacier Petchenko, Sary-Tash, Aitym-

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Nazar, Chatal, and Angren, the amount of the snow-period precipitation during the majority of years does not exceed 10 - 25 percent of the thawed snow layer (in water layer), then in the Pskem valley this precipitation over most of the time does not exceed 50 percent. If in the determination of disappearance of the snow layer at these meteorological stations we use as a base the actual date of positive temperatures, and if for meteorological station Pskem we take into account the thaw-period precipitation, the computed dates of disappearance of snow layer would be close to the actual dates.

**TABLE I**

Meteorological station	Station altitude above sea level (in meters)	Thickness of Snow Layer (in centimeters) at That Time	Dates of Disappearance of Snow Layer	Deviation from Actual (in days)
			Computed Actual	
Pechenga	4,150	400	26 July 12 July	+ 5
Usty-Tsch	3,700	212	5 May 9 May	- 3
Tyulyuk	2,100	20	11 April 17 April	- 6
Aksai-Pskem	2,700	120	12 April 5 April	- 7
Angren	2,200	196	5 April 14 April	- 9
Magadan	2,220	70	19 March 16 March	- 2
Saryn	2,000	61	12 March 10 March	- 18
Chatal	1,870	320	3 April 24 April	- 21
Pskem	1,770	350	20 March 4 April	- 15

Let us note that the deviations between the computed and actual dates of disappearance of snow layer indicate that, for locations where the length of snow-period precipitation does not exceed 25 percent, these deviations can be neglected. On the other hand, they indicate that the effect of local climate features can be very significant.

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position of the thaw rear for the first day of each month as well as its average daily displacement, in accordance with the relationship shown by Drawing 2, is given in Table II.

The following conclusions can be drawn from Table II.

(1) That the effect of thickness of snow layer upon the position of thaw rear is very great, especially during early spring when, due to low air temperatures, the intensity of thaw is not great. For example, on 1 April, for snow layer thickness of 20 millimeters, thaw rear is at the 2,870-meter level; whereas, for a thickness of 1,000 millimeters, thaw rear is below 1,000 meters, the difference in levels approaching 2,000 meters. In so approach autumn the differences in the position of thaw rear become smaller because of the high summer air temperatures capable of quickly thawing even a heavy snow layer.

(2) That the speed of displacement of the thaw rear is especially great at the time of commencement of intensive thawing embracing lower mountain zones; during this period displacement of the thaw rear may proceed faster than that of thaw front. Toward autumn the speed of displacement of thaw rear is naturally slowed down and reaches its minimum in September. This slow-down of thaw rear displacement will be even greater as it embraces the higher zones of the watershed when we consider<sup>sup</sup> the thickness of snow layer is usually increased, sometimes appreciably, with the increase in elevation (up to great altitudes at any rate), instead of remaining constant.

(3) That the difference in altitudes between the thaw rear and thaw front, for a snow layer thickness of 1,000 millimeters and above, is greatest during the initial stages of thaw (spring period), and decreases afterward (Table III). During autumn the difference

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in positions of the thaw front and thaw rear is at a minimum, as to be expected. Toward the first of October thaw rear could be located above the thaw front, due to the scarcity of September precipitation.

**TABLE II**  
Thickness of Snow Layer

Date	20 mm		100 mm		400 mm		1,000 mm	
	Average Daily Displace- ment elevation (m)	displace- ment (m)	Average Daily displace- ment elevation (m)	displace- ment (m)	Average Daily displace- ment elevation (m)	displace- ment (m)	Average Daily displace- ment elevation (m)	displace- ment (m)
1 January	3,100	0.0	32.4	below 1,000	32.4	below 1,000	32.4	below 1,000
1 February	3,100	0.0	32.1	1,000	32.1	1,000	32.1	1,000
1 March	2,000	26.1	1,150	31.9	1,000	31.9	1,000	31.9
1 April	2,170	23.1	2,500	27.0	2,600	29.7	2,200	25.0
1 May	3,170	15.7	3,210	20.6	3,270	23.2	3,250	25.0
1 June	4,150	12.2	3,920	13.6	4,000	14.2	3,740	16.3
1 July	4,520	6.8	4,360	9.0	4,250	8.1	4,030	9.8
1 August	4,730	2.9	4,640	1.3	4,400	4.8	4,200	5.5
1 September	4,620	0.0	4,660	0.0	4,680	2.7	4,300	3.3
1 October	4,620	46.8	4,640	-43.6	4,680	-36.5	4,300	-30.6
1 November	3,350	39.4	3,350	-31.1	3,350	-34.4	3,350	-34.4
1 December	3,320	39.4	3,320	32.0	3,320	2,320	3,320	32.0

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**CONFIDENTIAL****Table III****Thickness of Snow Layer**

<u>Date</u>	<u>20 mm</u>	<u>100 mm</u>	<u>400 mm</u>	<u>1,000 mm</u>
1 March	180	730	1,000	1,000
1 April	140	520	1,370	2,000
1 May	210	470	830	1,400
1 June	260	500	870	1,200
1 July	190	610	970	1,230
1 August	470	860	970	1,170
1 September	50	230	500	700
1 October	-550	-440	-240	-60

For a thick snow layer, simultaneous thawing may occur during spring over areas differing in elevation by more than 3,000 meters; and during summer for areas differing in elevation by more than 1,000 meters. Actually, the areas of simultaneous thawing will be somewhat smaller, since there are few places in Central Asia below 1,000 meters in elevation where the snow layer thickness is 1,000 millimeters or greater.

Drawing 2 indicates that for a snow layer of 20 millimeters (in water layer) the snow line is located at an approximate altitude of 4,600 meters, and for thickness of 2,500 millimeters it is located at 3,600 meters. This is in good agreement with the existing data on the elevation of the snow line. For example, according to S. V. Tolešnik (3) the average elevation of the snow line for southern and northern slopes is as follows:

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	Kilometers
Dzhungarskiy Alatau	3,400
Zailiyskiy Alatau	3,750
Terskoy Alatau	3,800
Khan-Tengri	4,250
Peter the Great	4,800
total	5,250

It must be borne in mind that the above data separates the different high-mountain sections, covering almost the entire mountainous region of Central Asia, with the exception of southern Kazakhstan.

In conclusion, it must be pointed out that we based our studies upon data of meteorological stations located in river valleys; in view of this the above relationships do not account for the effect of slope exposure.

[Bibliography follows]

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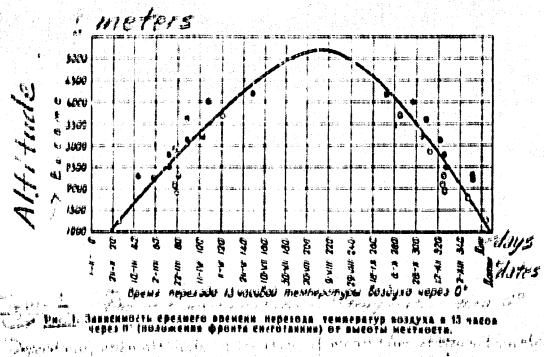
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**III**

Based on the author's diagram 1947.

[Note: This is a photostatic copy of the original figure.  
See page 5 here for a pencil sketch and captions.]



Drawing 1.

- END -

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